Turbo Coded OFDM / SC-FDE Techniques for MIMO BFWA Channels

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Broadband fixed wireless access (BFWA) is an ideal solution for providing high data rate communications where traditional landlines are either unavailable or too costly to be installed. However, the performance of BFWA systems has not been adequately characterized in the open literature. Consequently, in this paper we consider a number of alternative techniques to achieve high performance in these systems, including turbo convolutional coding (TCC), orthogonal frequency division multiplexing (OFDM), single carrier with frequency domain equalization (SC-FDE) as well as multiple-input multiple-output (MIMO) technology. The BFWA channel has been measured and six Stanford University Interim (SUI) models have been specified for particular scenarios [1]. In this paper we have adopted the SUI-3 model, which corresponds to average British suburban conditions. The line-of-sight (LOS) component is relatively small and the channel is slowly fading as well as mildly frequency selective.

In the first part of the paper, we consider single-input single-output (SISO) systems for BFWA applications. At the transmitter powerful channel codes, such as TCC [2], are concatenated with schemes that exploit frequency diversity, such OFDM and SC-FDE. Block interleaving and symbol mapping (BPSK, QPSK or 16-QAM) are performed, following channel encodingt the receiver, the transmitted symbols are recovered, the log-likelihood ratios (LLRs) of the corresponding bits are calculated [3], de-interleaved and passed to the iterative channel decoder.

We demonstrate that although the performance of turbo-coded systems is outstanding in the Additive White Gaussian Noise (AWGN) channel and also in the perfectly interleaved Rayleigh fading (PIRF) channel, neither temporal/frequency diversity methods nor channel coding improve performance in the SUI-3 channel. This is due to the fact that the channel is slowly fading and only mildly frequency selective. It is shown that turbo-coded OFDM systems perform better than turbo-coded SC-FDE systems using the Minimum Mean Squared Error (MMSE) criterion when the code rate is low. As the code rate increases though, the SC-FDE/MMSE-based system begins to outperform the OFDM-based system. However, a large BER performance gap remains between systems operating in a perfectly interleaved Rayleigh fading channel and identical systems operating in a SUI-3 channel. We conclude that it is therefore of paramount importance to exploit other forms of diversity, for example spatial diversity, to improve performance.

Accordingly, in the second part of the paper we consider MIMO systems for BFWA applications. In particular, we consider MIMO systems having two transmit antennas and one receive antenna (2T1R) as well as those having two transmit and two receive (2T2R) antennas, including the effect of antenna correlation. Two MIMO techniques are investigated. Firstly vertical BLAST (V-BLAST) is employed with the aim of increasing the data rate. Secondly space-time block coding (STBC) is applied with the aim of increasing the data reliability [4].

Configuration	E_b/N_0
SISO	
QPSK / AWGN	1.8 dB
QPSK / PIRF	2.9 dB
QPSK / SUI-3	12.4 dB
MIMO in SUI-3	
2T1R QPSK/STBC	8.6 dB
2T2R QPSK/STBC	6.4 dB
2T2R BPSK/VBLAST	13.9 dB

Table 1: SNR required for BER=10^{-3} of different turbo-coded OFDM schemes. The turbo encoder consists of two systematic RSC(7, 5) encoders, a random interleaver (size 1,000) while the code rate is 1/3. The turbo decoder applies the exact Log-MAP algorithm (8 iterations).

Calculation of the LLRs, which are exploited by the turbo decoder, are simple when STBC is applied and its complexity increases only linearly with the number of transmit antennas. On the contrary, the number of calculations required to calculate the LLRs rises exponentially when V-BLAST is used, since there is no orthogonality to be exploited. We show that with the application of MIMO techniques, the performance of turbo-coded systems is significantly improved in BFWA channels. In particular, iterative decoding produces a considerable coding gain, which clearly rises as the number of iterations rises from 1 to 8. The STBC architecture is also compared to the V-BLAST approach for a pre-defined throughput. No matter how frequency diversity is exploited (OFDM or SC-FDE), it is observed that systems employing turbo-coded STBC/QPSK, or turbo-coded STBC/16-QAM, perform better than turbo-coded V-BLAST/BPSK, or turbo-coded V-BLAST/QPSK respectively.

Concluding, MIMO partly alleviates the problems caused by the BFWA channel, OFDM is more efficient than SC-FDE only when the code rate is kept low, while turbo coding and iterative decoding can be used to further improve performance. Although V-BLAST offers high data transmission rates, STBC can achieve the same data rates by implementing higher constellations and, at the same time, offering considerably better reliability. Some of our results are summarized in Table 1.

References:

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